Reconciling public opinion and water quality criteria in South Africa

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Abstract

A definition of a "clean water lake" was compiled from the responses of over 3 000 recreational users of inland waters in the greater Pretoria and Cape Town areas to an open-ended question requiring respondents to define such lake. Visually aesthetic characteristics were found to be the most commonly cited means of determining the pollution status of a lake; namely, the absence of scums and excessive quantities of algae, clear water with low turbidity, and an abundance of wildlife. These characteristics were equated to common limnological variables such as chlorophyll *a* and Secchi disc transparency and a scale of values acceptable to the public created by reference to the survey and to the literature where necessary. These values were found to correspond to values used by water management authorities and limnologists to define lake trophic state.

Introduction

Water management professionals have tended to address the issue of water quality standards in isolation from the society which these standards are designed to protect (Hart and Allanson, 1984). In many cases, such treatment is warranted on the basis of the specialist knowledge that is available to the professional, but not generally known to the wider public (NALMS, 1988). However, this situation can lead to an information gap wherein the "man in the street" is expected to support, through rates and taxes, water body protection programmes or rehabilitation programmes that are meaningless to him/her. Public perceptions of environmental protection legislation, as a result, are of a set of standards, randomly selected and applied, over which the public has no control. This perception, in turn, leads to the professional view, partly confirmed in fact (Adler and Ackerman, 1981; Mynhardt *et al.*, 1979), of an apathetic and disinterested public.

Recently a groundswell of public environmental concern has begun to appear in Europe (Schuurman, 1984) and North America (Nix and Black, 1987), prompting Voiland and Duttweiler (1984) to ask "Where's the humanity? ....". In southern Africa, this concern, as it affects the water environment, has been expressed in respect of specific water quality problems (such as the water hyacinth infestation at Hartbeespoort Dam; Scott *et al.*, 1979 and the eutrophication of Lake McIlwaine; Thornton, 1982) and more generally by both professionals and general public in the aftermath of the recent drought (DWA, 1986; Thornton *et al.*, 1989)

This paper examines public opinion regarding water quality in South Africa and attempts to relate this to limnologically-based criteria for the management of water bodies in the region.

Methods

Assessment of public opinion

Data used in this study were gathered during the period February 1987 to January 1988 by means of two questionnaire surveys conducted amongst users and householders in the Pretoria area (principally at Hartbeespoort Dam) and users in the Cape Town area (at Zandvlei). In the Pretoria study, 465 pre-tested questionnaires were distributed to householders in a door-to-door survey of Kosmos and Pierre van Ryneveld Park and in a mail drop survey of users of the recreational sites at Hartbeespoort Dam maintained by the Transvaal Provincial Administration. The response rate was 35% with 153 questionnaires being returned. In the Cape Town study, an abbreviated form of the questionnaire, excluding some of the behavioural questions included in the Pretoria study, was used to obtain 2 917 responses from users of Zandvlei.

The questionnaires were designed to identify baseline water quality conditions acceptable to (predominantly) recreational users of the two inland water bodies. Respondents were asked to indicate their reason for, and frequency of, visitation; define a clean water, unpolluted lake; assess the water qualtiy of the water body where they were interviewed (or one with which they were familiar in the case of the Pierre van Ryneveld Park respondents); define the criteria upon which their assessment was based; indicate if and how much money they would be willing to commit in the form of additional taxes, fees and levies to ameliorate the problems they identified (if any), and provide some demographic information. In addition, the Hartbeespoort Dam study included several questions aimed at identifying specific parameters which respondents used to define a polluted water body and which influenced their behaviour to such a water body, and at defining a polluted water body. The questionnaires were designed to include both structured-response and open-ended questions, and full details of the surveys and their results are given by Thornton *et al.* (1989). The questions relating to this paper were open-ended.

Study sites

Hartbeespoort Dam (25°43'S, 27°51'E) is a large, warm monomictic, hypertrophic man-made lake located approximately 37 km west of Pretoria in the Transvaal Province of South Africa. The impoundment has been studied at intervals since its construction in 1925, and most recently has been the subject of an intensive monitoring programme and modelling study reported on by the NIWR (1985). The impoundment is principally an irrigation supply dam providing water to the Hartbeespoort Government Water Scheme area, but also serves as the water supply for the Hartbeespoort and Brits municipalities and as the centre of an active

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recreational industry which includes anglers, yachtsmen, power boaters and holiday visitors. The Transvaal Provincial Administration maintains three recreational sites on the lake at Schoemansville, Oberon and Kommandonek. The town of Kosmos is a small (221 dwellings) community on the north-western shore of the lake. Pierre van Ryneveld Park (East) is also a small (173 dwellings) community located in the town of Verwoerdburg adjacent to the western boundary of the city of Pretoria, well away from the immediate influence of the water body (this community served as a control from which to assess the degree of bias introduced into the study by the vested interests of the lakeside dwellers; Thornton *et al.,* 1989.

Zandvlei (34°05'S, 18°28'E) is a small, well-mixed estuarine lake located on False Bay adjacent to the Cape Town suburb of Muizenberg in the Cape Province of South Africa. This water body was the subject of a comprehensive report by Morant and Grindley (1982). The lake is primarily a recreational venue popular with yachtsmen and board sailors in the Cape Town region. Much of the lake shore is public parkland maintained by the City of Cape Town.

TABLE 1
SELECTED MORPHOLOGICAL AND LIMNOLOGICAL CHARACTERISTICS OF HARTBEESPOORT DAM AND ZANDVLEI

Characteristic	Hartbeespoort Dam	Zandvlei
Volume (10^6 m^3)	195	1,5
Surface area (km^2)	20	1
Maximum depth (m)	32	2
Mean depth (m)	9,6	1,5
Water residence time (a)	0,9	0,06
Total phosphorus (mg ℓ^{-1})	0,45	0,11
Total nitrogen (mg ℓ^{-1})	0,97	0,42
Chlorophyll *a* (mg m^{-3})	40	25
Secchi disc transparancy (m)	0,8	0,6
Flora	*Microcystis*-dominated	*Potamogeton*-dominated

TABLE 2
WATER QUALITY CHARACTERISTICS OF A "CLEAN WATER" LAKE IDENTIFIED BY RESPONDENTS (BY FREQUENCY OF OCCURRENCE) (%)

Characteristic	Hartbeespoort Dam	Zandvlei
No excess algae or scums	13	27
No excess weed growth	-	10
No smells or odours	13	3
No chemical pollution	3	1
No litter/debris/obstacles in water	14	3
Clear water, low turbidity	29	23
Good/safe hygienic quality	8	8
Well-flushed	1	5
"Living" water (fish/wildlife etc.)	15	4
Sandy bottom	-	1
Well-oxygenated, low nutrients	1	-
Picturesque appearance	2	-
Other (combinations of above)	-	15
Don't know	1	-

Table 1 summarises the key morphological and limnological characteristics of the two water bodies on which this study is principally based. It should be noted, however, that respondents made reference to many other water bodies in answering questions relating to the definition of "clean" and "polluted" lakes. Hence, the responses obtained and discussed in this paper are of more general applicability than to Hartbeespoort Dam and Zandvlei alone (Thornton, 1987a).

Results

Table 2 summarises the characteristics identified by respondents to the questionnaire surveys as being representative of a clean, unpolluted water body. Two categories of response are given; one that describes a clean water lake in terms of negative characteristics (e.g. no odours, etc.) and one that uses positive characteristics. In other words there was a presence/absence dichotomy in replies received. Considering the negative attributes first, the dominance of aesthetic characteristics, predominantly visually aesthetic characteristics, is apparent. This is a function of the propensity of the public to use visual criteria in the assessment of water quality (Thornton *et al.*, 1989). These characteristics could possibly be seen as suggesting that the respondents had a typological concept of a polluted lake (Table 3) and thought of a clean lake as not having certain attributes of this conceptual lake. If this is the case, it has far-reaching implications for public expectations in respect of water quality and may explain in part the continued recreational use of impacted water bodies that would be unacceptable elsewhere in the world. In effect, it makes a statement about the personal values of the respondents: persons who place a high value on material well-being are less supportive of water resource preservation (Pierce, 1979). This attitude would contribute directly to the apparent lack of concern for the environment identified in previous studies (Adler and Ackerman, 1981).

On the other hand, the positive attributes of clean water-bodies identified by respondents show that they have a good deal more insight into the functioning of aquatic systems, although reflecting as well some popular misconceptions of pollution which are discussed further below. The visually aesthetic characteristics are still present (cf. clear water and picturesque appearance) but there is a greater range of issues addressed, including many limnological parameters such as flushing rate, nutrient status and productivity (e.g. well-flushed, low nutrients and "living" water).

The attributes of a "polluted" water body are, for the most part, the antithesis of those characteristics used for a clean lake (Table 3). Thus the emphasis remains on visually aesthetic characteristics such as scums, litter and debris. Odours and fish kills are also oft-selected characteristics. The former may be related to the nature of flora and stratification at Hartbeespoort Dam (Jarvis, 1988) which is more prone to generating unpleasant odours from decomposing blue-green algae and an anoxic hypolimnion than the macrophyte flora of shallow Zandvlei. Table 2 shows that the absence of odours rated highly in the Transvaal survey but relatively lowly in the Cape survey as an indicator of clean water.

The results, whilst demonstrating a degree of consistency in terms of the nature of the characteristics selected by respondents to describe a clean water lake also bring out some interesting differences in perception that are related to the general limnology of the two systems studied (Tables 1 and 2). The emphasis on odours that was recorded at Hartbeespoort Dam but not at Zandvlei has been discussed above. The differing flora which seems to be part of the reason for the differing emphasis was also apparent from the fact that Hartbeespoort Dam respondents mentioned excessive algal growth exclusively, whilst Zandvlei respondents also specifically referred to weed growth, alluding to the dominance of the lake flora by *Potamogeton*. The emphasis on litter at Hartbeespoort Dam, as opposed to Zandvlei, was somewhat surprising, but is possibly due to the fact that much of the Zandvlei shoreline is in the public domain and is cleaned at regular intervals by the City of Cape Town. This is in contrast with the situation at Hartbeespoort Dam where litter may accumulate to a greater extent before being collected; hence, the litter problem may be more visible. Also tempering the litter accumulation on Zandvlei is the generally higher wind speeds recorded which act to remove litter from the public areas of the vlei (the dominant south-easterly wind pushes litter onto the northern nature reserve shore of Zandvlei; compare Morant and Grindley, 1982, and NIWR, 1985, for velocity data).

TABLE 3
WATER QUALITY CHARACTERISTICS OF A "POLLUTED" LAKE IDENTIFIED BY RESPONDENTS (BY FREQUENCY OF OCCURRENCE (%))

Characteristic	Hartbeespoort Dam
Excessive enrichment	5
High turbidity	8
Low oxygen	11
Excessive algae, scums (green)	20
Refuse, debris, oil films	23
Dead fish	10
Odours and smells	14
"Unhealthy"/unsafe water	5
Dead vegetation in water	1
"Slimey" appearance	2
Don't know	1
	n = 153

The greater emphasis on "living" water at Hartbeespoort Dam was probably related more to the nature of the activities in which the respondents to that survey were engaged than to the environment generally, but could have environmental significance as well. Respondents to the Hartbeespoort Dam study were predominantly anglers (Thornton, 1987 a) who have an interest in the lake fauna, in contrast with the Zandvlei respondents who were primarily boating enthusiasts (City of Cape Town, 1988). On the other hand, fish kills occur more frequently at Hartbeespoort Dam and decaying algal blooms create an atmosphere that does not relate well to "living" water (Jarvis, 1988). The "well flushed" response at Zandvlei was probably the result of the perception of that water body as an estuary as opposed to a lake, although the concept of moving water being less polluted than standing, stagnant water was mooted by many respondents. Similarly, the greater number of combination responses (the category "other") at Zandvlei was probably the result of demographic differences between groups of respondents, many of whom were students having a wider exposure to environmental issues than respondents at Hartbeespoort Dam (Thornton *et al.*, 1989; Grieve and Van Staden, 1985).

Discussion

The selection of water clarity as the dominant characteristic of water quality (inclusive of the related concept of absence of surface scums) is consistent with the use of visual indicators of pollution (David, 1971). Similarly, the broader range of indicators used at Hartbeespoort Dam reflects the effect of trophic status on public perceptions of water pollution (Kooyoomijian and Clesceri, 1974). The issues identified can be described by a range of limnological parameters in most cases (Table 4). A major exception is the characteristic "picturesque appearance" which includes, in a qualitative way, the complete range of characteristics identified by respondents, and hence compares with the more general limnological trophic state descriptors such as oligotrophic, mesotrophic or eutrophic. Similarly, the term "slimey" appearance could be related to eutrophy or hypertrophy.

Water quality criteria

Table 4 presents a table of equivalents giving both the public characteristic and limnological parameter for a number of water quality criteria. The range given has been derived from a number of sources, but principally from the work of Walmsley (1985), Kempster *et al.* (1982), Thornton (1987b) and Thornton and Rast (1989). These values represent a best estimate of those levels which, if exceeded, would give rise to an assessment of "polluted" by the "man in the street".

Walmsley (1985) used a frequency distribution of chlorphyll *a* values derived from 24 South African man-made lakes to identify that level at which nuisance amounts of phytoplankton would occur, or, in other words, that concentration of chlorophyll at which a water body would be classed as eutrophic by an observer. He found that 14 mg m^{-3} was indicated. Thornton and Rast (1989) extended this data base to include 89 reservoirs in southern Africa and the semi-arid American southwest and arrived at a similar figure as a median in the range of 10 to 20 mg m^{-3}. Viljoen and Van der Merwe (1986) have reported that the Rand Water Board Works experiences algal problems at chlorophyll concentrations in excess of 20 mg m^{-3}, so it would appear that the 15 mg m^{-3} upper limit on mesotrophy has practical as well as aesthetic meaning.

The Secchi disc transparency value of 1 to 2 m has been derived from user comments regarding the visibility of their feet in depths of water ranging from knee-deep to shoulder-deep. In examining the large data base on semi-arid reservoirs, Thornton and Rast (1989) found that this value was common (1,1 m being the median transparency) in the majority of lakes surveyed. Thus, in many cases, a 1 m transparency would represent an achievable objective.

Hygienic criteria have been derived from the published literature as being the minimum requirement for contact recreation (Thornton, 1987b; Lusher, 1984). This conforms to the public's requirement for "safe" water.

Water residence times in semi-arid reservoirs are generally less than 1 year (Thornton and Rast, 1989). Whilst these rates are higher than temperate zone flushing rates, it is only at the lower end of the range that the "well flushed" characteristic could be applied. At water residence times of less than 0,2 year, washout of phytoplankton occurs and aesthetic benefits occur (Walmsley, 1980). Such a high flushing rate is, however, unrealistic in most cases, especially where impoundments are designed to serve a storage function and so a rate of less than 1 year might be a better equivalent from the practical point of view.

"Living" water can be defined in a number of ways. "Living" water is equated with dissolved oxygen levels of greater than 4 mg ℓ^{-1}, below which fish are subject to oxygen stress and potential death (Table 4; Cochrane, 1987). This concept may also be linked with that of species diversity, balanced algal and macrophyte growth and low nutrient concentrations, although these factors were often mentioned as descriptors in their own rights. Similarly, the characteristic "no unpleasant odours" may be linked to hydrogen sulphide, which becomes offensive to human olfactory

TABLE 4
WATER QUALITY CHARACTERISTICS IDENTIFIED BY PUBLIC AND LIMNOLOGICAL EQUIVALENTS

Characteristic	Limnological parameter	Range
No excess algae	Chlorophyll *a*	< 15 mg m^{-3}
Clear water	Secchi disc transparency	1 to 2 m
Hygienic water	Coliform bacteria	$< 100/100$ mℓ
Well-flushed	Water residence time	$\pm 0,2$ to 1,0 year
"Living" water	Dissolved oxygen	> 4 mg ℓ^{-1}
No smell	Hydrogen sulphide	$< 0,4$ mg ℓ^{-1}
Abundant wildlife	Species diversity	-
No excess weeds	Biomass	?
Low nutrients	[P], [N]	$< 0,05$ mg ℓ^{-1}P $< 0,2$ mg ℓ^{-1}N
No obstacles	Depth, mean depth	> 1 m
No litter/debris	Suspended solids	?
No chemical pollution	Pesticides, metals, radioactivity, etc.	(various, but generally nil)

organs in excess of 0,4 mg ℓ^{-1}, as well as to algal growth. At Hartbeespoort Dam, decaying scums of blue-green algae often create odours as unpleasant as those of hydrogen sulphide (Jarvis, 1988; personal observation).

Abundant wildlife, which includes the concept of a diverse fauna (inclusive of avifauna; see below), was often cited by respondents as characteristic of good quality water, especially during the Hartbeespoort Dam survey (Table 2). Numerous measures of species diversity as an index of water quality exist, ranging from the biotic index of Chutter (1972) to computer-based expert systems such as the RCS (Danilewitz *et al.*, 1988). Many of these have specific application, but generally they quantify in some measure the variety and abundance of various aquatic organisms and could give numerical expression to the concept of abundant wildlife.

Quantifying nuisance levels of aquatic macrophytes is also difficult and the definition of a range, although techniques exist (Gaudet *et al.*, 1981), would tend to be site specific.

Thornton (1980) has suggested that southern African man-made lakes can tolerate higher nutrient loadings than temperate lakes before showing symptoms of eutrophication. This hypothesis was generally confirmed by the study of Thornton and Rast (1989) who showed that most reservoirs in the semi-arid zone had total phosphorus concentrations of about 0,05 mg ℓ^{-1} before being assessed by observers as being eutrophic. Similarly, total inorganic nitrogen values were also somewhat higher, although the value of 0,2 mg ℓ^{-1} in Table 3 represents a median for a data set comprising nitrogen-poor North American impoundments (mean [TN] = 0,12 mg ℓ^{-1}) and nitrogen-rich southern African water bodies (mean [TN] = 0,47 mg ℓ^{-1}). These values, and more importantly the ratio between them, are critical to the development of algal blooms (Thornton, 1982) and, hence, nutrient concentration standards should be viewed in terms of the algal biomass produced rather than as absolute values.

Depth criteria, as applied to the recreational use of water bodies, generally relate to the use of the water body for sailing, board sailing, swimming or boating and must be sufficiently deep to allow passage of keels or motors. The mean depth value in excess of 1 m would permit the use of most inland water smallcraft without hindrance. As most water bodies exceed this minimum, the range selected would represent a practically achievable objective.

Finally, issues such as litter and debris and chemical pollutants were also identified by the public. The latter requirements were generally for nil contamination and this is consistent with the pollution control regulations which prohibit the discharge of constituents that are harmful to life forms (DWA, 1986; Kempster *et al.*, 1982). Similarly, the presence of litter and debris is probably inconsistent with existing legislation (DWA, 1986). Thus, there would appear to be significant concensus between public opinion and achievable water quality standards as determined by available limnological criteria.

Popular misconceptions

A number of popular misconceptions were also highlighted during these surveys and have had to be discounted in producing the table of equivalents (Table 4). The most persistent is that any fish kill is the result of water quality or water pollution problems. Whilst fish kills due to deoxygenation do occur (Marshall, 1981), most winter kills of fish would seem to be due to thermal effects (Cochrane, 1987). In contrast, it appears that the presence of a diverse fauna of any description is equated with a healthy water body. Avifauna, in particular, were often mentioned as a characteristic of a clean lake, although there is an abundance of evidence to suggest that this is not always the case (Day, 1988; Jarvis, 1982). It is not possible to resolve this misconception with the data available, but it may be that the species of avifauna as well as simple diversity may be important to the public perception in this case. There was also a tendency to equate turbidity with pollution regardless of the source of the suspended sediments. The large catchment to lake area ratio required to maintain yields in many reservoirs contributes to the presence of sediment in some systems (Alexander, 1985; Thornton and Rast, 1989), whilst resuspencion of near-shore sediments contributes to turbidity in others (Kirk, 1985). These issues were, however, minor when examined in the context of the entire water quality scheme derived from the questionnaire surveys.

Conclusions

Water quality criteria such as transparency, chlorophyll *a* and nutrient status have been proposed as equivalents of the public's demand for clear water lakes with balanced algal/plant growth. Of these, chlorophyll *a* would seem to have merit as the single most comprehensive criterion as it will have meaning to the water manager and the general public (when translated into terms of "greenness"). Thus, the water quality aspirations of the general public and those of the water manager would seem to be reconcilable. The characteristics used by members of the public to assess the pollution status of a water body (having scientific equivalents) should be borne in mind when designing water body rehabilitation schemes or lake protection programmes and when such schemes are proposed to the public. The current information gap between the "man in the street" and the decision-maker can be closed.

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